

REFRACTORIES FOR THE GLASS INDUSTRY

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PRODUCTION OF REFRACTORY CONCRETES AND PRACTICE IN USING THEM IN GLASS-MELTING AGGREGATES

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The refractory concrete items and refractory pastes used in glass-melting aggregates manufactured by Semiluki Refractory Factory are presented. Their specifications are reported — strength, density, porosity, etc.

In glass production, refractory concretes — unfired composite materials — have already been used for more than 30 years. Use of a new generation of concretes — low-cement concretes — has expanded in the past five years. The cement content in them is a maximum of 8 – 10%, which allows using a wide range of fillers — from corundum to chamotte — without worsening the high-temperature properties. Even concretes of chamotte composition have better high-temperature properties than the indexes for traditional fired chamottes due to the minimal content of calcium oxide bound in high-melting hexaaluminate. In addition, such a low cement content in the new concretes reduces to the minimum the negative effect of the destructive processes that take place in dehydration and recrystallization of the calcium hydroaluminates in cement, which are the cause of the well-known weakening interval in traditional concretes.

In modern furnace building, the small-piece lining is being replaced by the monolithic lining and assembly of pre-fabricated slab articles. For the users, this is freedom of design using articles of different shapes and sizes, reducing the number of joints in the refractory lining due to the use of large blocks, and mechanization and continuity of assembly of the lining due to the accuracy of the geometric dimensions of the refractories. Refractory production is changing from semidry molding technologies to vibromolding of articles from low-cement thixotropic pastes.

The low-cement concrete mixture is thixotropic, i.e., it acquires fluidity in vibration, which allows it to fill a concreting volume (mold) of any configuration. In vibration, the particles of the material are compacted without destruction

and deformation, in contrast to the method of semidry molding, where elastic expansion of the particles causes the appearance of internal stresses and perturbation of the continuity of the body of the stock, i.e., crack formation. This is a very important reason why semidry molding is being replaced by vibrocasting, especially in production of large items.

Due to vibromolding, the structure of concretes becomes microporous, and the pores have a round structure and basically do not communicate, so that the channel porosity of concrete articles is much lower than for fired rammed articles. How are the properties of concrete and traditional fired refractory articles comparable? Refractory concretes are more thermostable and less heat-conducting than fired items of the corresponding composition and have a lower CLTE [1]. The drawbacks of concretes are always the low abrasion resistance. Technology for production of high-quality cements and materials for the matrix constituent of concretes

**Fig. 1.** Feeder refractory ware.

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Fig. 3. Bottom block for tin melting tank.



Fig. 2. Bottom block before shipment.

has now been developed and allows increasing the strength of the concrete after processing by the manufacturer to 100 MPa and higher. The compositions of the new concretes are multicomponent; although this complicates the production technology, it gives it flexibility and the possibility of modifying the composition of the concrete in accordance with the servicing conditions.

The development of low-cement concretes for use in glass-melting furnaces at Semiluki Refractory Factory was begun in 2004 in two directions — complexly shaped feeder refractory ware and prefabricated slabs for lining the bottoms of glass-melting furnaces and tin melting tanks (Figs. 1 – 3). Nine concrete compositions have been specially developed for articles for glass-melting production (see Table 1). After

TABLE 1

Index	Articles made of low-cement concretes for glass-melting furnaces								
	VKS-95	VMKS-85	VMKS-76	VMLS-65	VMKRS-50	VMLB	VShBS	VTsMS-13	VTsMS-25
Maximum service temperature, °C	1700	1650	1600	1550	1500	1500	1450	1600	1600
Chemical composition, %:									
Al ₂ O ₃	96 – 98	86 – 87	76 – 77	66 – 67	50 – 52	63 – 64	43 – 44	76 – 77	62 – 63
Fe ₂ O ₃	< 0.2	< 0.3	< 0.5	< 0.8	< 1.3	< 1.0	< 1.4	< 0.2	< 0.2
CaO	1.2 – 1.6	1.2 – 1.6	1.2 – 1.8	1.2 – 1.8	1.6 – 1.8	1.6 – 1.8	1.7 – 2.0	1.2 – 1.6	1.2 – 1.6
ZrO ₂	–	–	–	–	–	–	–	13 – 14	25 – 26
Compressive strength, N/mm ²	40 – 55	40 – 55	45 – 55	45 – 55	45 – 50	45 – 55	40 – 45	45 – 55	40 – 50
Density, g/cm ³	3.15 – 3.20	2.85 – 2.95	2.75 – 2.85	2.55 – 2.65	2.35 – 2.40	2.45 – 2.50	2.15 – 2.19	3.15 – 3.20	3.20 – 3.25
Open porosity at 1400°C, %	12 – 14	14 – 17	14 – 17	15 – 17	16 – 18	16 – 18	18 – 20	16 – 17	16 – 17
Residual linear changes, %, at temperature, °C:									
1600	0.2	0.4	–	–	–	–	–	0.6	0.5
1500	–	–	0.4	0.4	–	0.5	–	–	–
1400	–	–	–	–	0.2	–	0.4	–	–
Refractoriness, °C	> 1800	> 1800	> 1800	> 1750	> 1750	> 1750	> 1700	> 1750	> 1750
Initial deformation temperature under load, °C	> 1650	> 1600	> 1550	> 1500	> 1450	> 1500	> 1400	> 1600	> 1600
Relative linear elongation in 20 – 1200°C temperature range, %	0.92	0.86	0.75	0.73	0.68	0.72	0.66	0.89	0.90
Thermal conduction at 500°C, W/(m · K)	2.30	1.90	1.70	1.55	1.30	1.50	1.20	2.30	2.30
Thermostability,* number of heating-cooling cycles (1300°C, water) before cracking or destruction	5/25	4/25	4/20	4/20	3/15	3/15	3/15	15/35	15/35

* Articles heat treated at 1000°C.



Fig. 4. Bowl (a) and hole (b).

four years of production and delivery of low-cement concrete articles to glassworks, we can sum up the experience in their production and use.

Feeder refractory ware. Features: complex configuration, including narrow edges in glass mixers; thin walls, channels, beads; low diameter-to-length ratio (articles long and thin) — for rams; complex configuration and impressive size — bowls (Fig. 4a). Hence, the complexity of structural processing and mechanical filling of molds. The first articles made of low-cement corundum concrete — rotating cylinders — were tested at Solnechnogorsk Glassworks and the first rams and stirrers were tested at Gusev Crystal Factory. The results of the first months of tests confirmed the concretes have elevated glass stability and work well in contact with the glass melt. Later tests on glass stability in dynamic conditions in V. G. Shukov Belgorod State Technological University confirmed this [2].

However, it was subsequently necessary to modify the composition of the concrete to increase its fluidity to fill molds of complex configuration without defects, and this was done for the basic brands of concrete. The work on selecting the composition for such items as the hole (Fig. 4b), since the item has thin walls and special strength is required of the concrete. By contacting users and working together

with them, much could be resolved and it was unambiguously shown that such complex articles could be made with “concrete” technology. During 2007 and the beginning of 2008, 11.2 tons of items of corundum, zirconium – mullite, and mullite – corundum compositions were manufactured.

Prefabricated slabs for lining the bottom of the glass-melting furnace — the bottom block. The first delivery in 2005 involved a complete set of articles for two furnaces for Sitall Co. Chamotte concrete with a strength of 40 – 45 MPa, porosity of 18 – 20%, and lower CLTE and thermal conduction than the traditionally used MCM block was specially developed. Three years of use confirmed the validity of this development, and the experience in using prefabricated concrete slabs in glass melting was successful.

Today more than 1500 tons of blocks have been delivered to glassworks in Russia and only positive feedback has been obtained from the users. There are now more than 25 enterprises in the glass industry that use concrete articles. In addition to feeder refractory ware and the bottom block, burner blocks, feeder channel covers, and slide valves are supplied.

Users of Refractory Concrete Articles

Svet (Mozhga)	VShBS
Starglass	VTsMS-13,* VTsMS-25*
Solstek	VMLS-65
Aksaisk Glassworks	BShBS, VMKS-76
Lunacharskii Glassworks	VKS-95*
Gusev Crystal Factory	VMLS-65, VKS-95
Sintez	VMKS-76, VMLS-65
Krasnoe Ekho	VMKS-76
Tver'steklo	VKS-95*
Experimental glassworks (Gus'-Khrustal'nyi)	VKS-95, VMKS-76, VMLS-65
Simvol	VShBS
Mailuu-Suuiskii Electric Lamp Factory (Kirgiziya)	VShBS
Dmitrovsteklo	VShBS
Ekran (Novosibirsk)	VShBS, VMLB
Kamyshin Bottle Glass Factory	VMLS-65*
Armavir-Steklo	VShBS
Borisov Glass	VKS-95*
Zaprudnya-Steklotara	VMKS-76
Tver' Glassworks	VKS-95*
Kamensk Bottle Glass Factory	VMKS-76*
Sitall	VShBS
Balakhninskoe Glass	VMLS-65*
Chagodoshchenskii Glassworks	VShBS, VMLS-65
Tuimazysteklo (Bashkiriya)	VShBS
Kursk Medical Glass Factory	VKS-95
Egermann Bohemian Glass Factory (Czech Republic)	VShBS, VMLB, VMKRS-50, VKS-95

* Feeder refractory ware.

At the end of 2007, an order was filled for concrete articles for a Bohemian glass factory in the Czech Republic. The

factory manufactures glass of very complex compositions, and high-quality refractories that do not cause flaws are required for lining the furnaces. The Czech glass makers did not immediately make a decision on purchasing unfired concrete articles. However, the technical study conducted by Czech specialists confirmed the suitability of our materials. Rigorous requirements were imposed for the constancy of the volume of the materials in high-temperature conditions, and our concretes totally satisfied these requirements.

There is another problem that arises for users on first contact with concrete articles: is a special regime required for preparing the concretes for use? We know that a special regime with rigorously fixed temperature elevation rates in different stages is required for heat treatment of concretes. This is so, but only for the 400 – 500°C temperature range, i.e., in the process stage at the manufacturer's. The concretes are insensitive to subsequent temperature elevation, and the regime of heating up the thermal aggregate, established for other articles used in the lining, is usually adequate. An exception is the case where the concrete has to work at low temperatures and in a medium of a complex reducing composition, for example, in the protected atmosphere of a tin melting tank. Only then is a special requirement imposed — when the tank goes into the working regime, attaining the temperature of 900 – 1000°C is mandatory in the absence of high humidity or the processing temperature is brought by the manufacturer to this value. As practice has shown, in all

other cases of using concretes in glassworks' thermal aggregates, no special regimes are required.

We found that increasing the temperature of the first processing of concrete to 1400°C (firing temperature of traditional refractories) does not markedly improve the quality of the articles, which once again confirms the basic advantage of "concrete" technology for the manufacturer — high-temperature firing is not necessary, which does not reduce the performance reliability of the glass-melting aggregate.

The concretes developed by Semiluki Refractory Factory Co. proved themselves as refractories for glass-melting furnaces. They have carefully developed compositions and are distinguished by simple molding technology that allows stably obtaining a quality product. Users have been purchasing dry mixtures and manufacturing the required articles on site for several years now (Solnechnogorsk Glassworks, Gusev Tsentr-Steklo-Gaz SIA).

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